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UNITED STATES DEPARTMENT OF AGRICULTURE

In cooperation with the Minnesota, North Dakota, South Dakota, Wyoming, Nebraska, Kansas, Texas, Iowa, Wisconsin, and Michigan Agricultural Experiment Stations and the Dominion of Canada Department of Agriculture

DEPARTMENT CIRCULAR 365

Washington, D. C.

February, 1926

RELATIVE SUSCEPTIBILITY OF SPRING- WHEAT VARIETIES TO STEM RUST

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IMPORTANCE OF RUST RESISTANCE

Black stem rust, *Puccinia graminis tritici* (Pers.) Erikss. and Henn., probably causes greater losses to the spring-wheat crop than all other diseases combined. According to estimates made by the Plant-Disease Survey of the United States Department of Agriculture, stem rust has caused losses of spring and winter wheat during the past 10 years ranging from 665,000 bushels in 1918 to about 180,000,000 bushels in 1916, with an average annual loss of nearly 38,000,000 bushels of wheat in the 13 North-Central States. The actual losses from stem rust alone may be somewhat below these estimates, but it is evident that, next to seasonal precipitation, stem rust is the most important factor in limiting the yields of wheat in the northern spring-wheat region.

The Red Fife and Haynes Bluestem varieties, formerly the leading hard red spring wheats grown in the Northern States, are very susceptible to rust. The varieties which largely replaced them, such as Preston and Marquis, are almost as susceptible, although

¹The writers wish to acknowledge the assistance of M. N. Levine, associate pathologist, Office of Cereal Investigations, in recording many of the rust percentages and for assistance in compiling the data.

Marquis sometimes partly escapes rust injury owing to its slightly earlier maturity. In recent years Ruby and Kota have partly replaced Preston and Marquis, because Ruby is earlier than Marquis and more often escapes rust and because Kota is more resistant to rust attack under field conditions. The rust resistance of durum varieties had been emphasized for many years, particularly after the rust epidemic of 1904. The growing of this class of wheat more than kept pace with the demand. The growing of durum wheat in the spring-wheat sections, where it is well adapted, has been the most important method of reducing rust losses, and until recently it has been the only method available to individual farmers. The limited market for durum wheat in comparison with that of hard red spring wheat has necessitated the growing of a larger proportion of the latter type in spite of the rust menace.

Epidemics of black stem rust have occurred during each of the past six years in all or parts of the northern spring-wheat region. The discovery or breeding of productive rust-resistant wheats of good milling and baking quality would result in greatly reducing losses from black stem rust. The data here presented show the relative susceptibility to black stem rust of the leading hard red spring and durum varieties which are commercially grown. Data are also included on some hybrid productions and varieties which are of promise in breeding for rust resistance. The value of certain varieties for commercial growing in order to reduce rust losses also is considered.

SCOPE OF THE EXPERIMENTS

In the cooperative experiments with spring-wheat varieties conducted by the United States Department of Agriculture and various State stations, the percentages of infection of stem rust usually have been recorded whenever rust occurred. Data on a number of spring-wheat varieties grown at seven stations in the northern half of the Great Plains area have been presented by Clark, Martin, and Smith² and from two stations in North Dakota by Stoa.³ It was shown that the durum wheats were more or less resistant, three of them—Acme, Monad (D-1), and Pentad (D-5)—being especially resistant to stem rust. Early-maturing varieties of common wheat showed a lower percentage of rust infection than late-maturing varieties. Differences in rust susceptibility of a number of winter and spring wheats at Manhattan, Kans., were shown by Melchers and Parker.⁴

Beginning in the spring of 1919 uniform nurseries of spring-wheat varieties were sown each year at from 8 to 19 experiment stations in the northern Great Plains and prairie regions, for the purpose of determining the relative susceptibility of spring-wheat varieties and the distribution of physiologic forms of black stem rust of wheat. In 1920 and 1921 most of the varieties were grown at 8 and 10 experiment stations in Canada and in 1924 some of the varieties were grown at 4 stations in Texas. From 20 to 31 varieties have been sown at a uniform rate each season. A total of 33 varieties was grown in these experiments.

² Clark, J. A., Martin, J. H., and Smith, R. W. Varietal experiments with spring wheat on the northern Great Plains. U. S. Dept. Agr. Bul. 873, 47 pp., illus. 1920.

³ Stoa, T. E. Varietal trials with spring wheat in North Dakota. N. Dak. Agr. Exp. Sta. Bul. 149, 54 pp., illus. 1921.

⁴ Melchers, L. E., and Parker, J. H. Rust resistance in winter-wheat varieties. U. S. Dept. Agr. Bul. 1046, 32 pp., illus. 1922.

TABLE 1.—Number of varieties of spring wheat and emmer grown in the uniform rust nurseries at 39 experiment stations, together with the names of the cooperators at each station, during one or more of the six years from 1919 to 1924, inclusive

Experiment station	Number of varieties						Cooperators
	1919	1920	1921	1922	1923	1924	
UNITED STATES							
Prairie (subhumid):							
Crookston, Minn.			24	22	24	24	E. R. Clark, R. S. Dunham.
Duluth, Minn.			13	8	24	24	M. J. Thompson.
Coon Creek, Minn.				17	24	9	G. H. Nesom.
Golden Valley, Minn.			16				Do.
St. Paul, Minn.	20	20	24	22	24	24	Olaf S. Aamodt, H. K. Hayes.
Morris, Minn.			24	22	24		R. O. Bridgford.
Waseca, Minn.				22	24	24	R. E. Hodgson.
Fargo, N. Dak.	17	20	24	22	24	24	W. E. Brentzel.
Brookings, S. Dak.	20		24	22	24	24	Mathew Fowlds, A. T. Evans.
Madison, Wis.			24	22	24	24	J. G. Dickson.
Chatham, Mich.				22	24	24	G. H. Coons, J. E. Kotila.
Ames, Iowa.	20		24	22	24	24	S. M. Dietz.
Lincoln, Nebr.	20	19		22	24	24	T. A. Kiesselbach.
Manhattan, Kans.	20						L. E. Melchers.
Great Plains (semiarid):							
Langdon, N. Dak.			24	22	24	24	W. E. Brentzel, L. Jorgenson.
Edgeley, N. Dak.			24	22	24	24	W. E. Brentzel, O. A. Thompson.
Mandan, N. Dak.	20	20	24	22	24	24	J. C. Brinsmade, jr.
Dickinson, N. Dak.	20	20	24	22	24	24	R. W. Smith.
Redfield, S. Dak.				22	24	24	Samuel Garver.
Highmore, S. Dak.	20	20					E. S. McFadden.
Newell, S. Dak.	20						A. D. Ellison.
North Platte, Nebr.						24	G. F. Sprague.
Archer, Wyo.	20	20		22	24	24	A. L. Nelson.
Akron, Colo.	20	20	24	22	24		F. A. Coffman.
Amarillo, Tex.	20						J. F. Ross.
South:							
College Station, Tex.						10	A. H. Leidigh.
Denton, Tex.						23	A. H. Leidigh, P. B. Dunkel.
Temple, Tex.						23	A. H. Leidigh, A. B. Cron.
Angleton, Tex.						23	A. H. Leidigh, V. E. Hafner.
CANADA							
Manitoba:							
Winnipeg.		20	24				W. P. Fraser.
Brandon.		19	24				Do.
Morden.		20	24				Do.
Saskatchewan:							
Scott.		20	24				Do.
Rosthern.		20	24				Do.
Saskatoon.		17	24				Do.
Indian Head.		19	24				Do.
Alberta:							
Edmonton.		20	24				Do.
Vermilion.			24				Do.
Lacombe.			24				Do.
Number of stations.	13	16	24	19	19	22	

The rates of sowing have varied slightly in different seasons, but usually about 12 to 15 grams per rod row were sown. At some of the stations the complete set of varieties was not sown each year. Beginning in 1921 two sets of nursery rows were sown at University Farm, St. Paul, Minn., one set in the plant-pathology nursery, which was artificially inoculated with several physiologic forms of wheat stem rust, and the other in the agronomy nursery where natural infection only took place. Nursery rows were sown both on sandy upland and in a peat bog at Coon Creek, Minn., in 1923 and 1924. In 1920 the nursery was sown at eight stations and in 1921 at 10 stations in western Canada, in addition to those in the United States. The results obtained at these Canadian stations are presented along with those obtained in the United States. Data also

are presented from four stations in Texas, at which some of the varieties were grown in 1924.

Seed for the uniform nurseries was weighed out and packeted in Washington, D. C., using the same lot of seed of each variety for all stations except in 1920, when the cooperators used seed obtained from the rust nurseries in 1919 at their respective stations. Since 1921 the varieties, with a few exceptions, have been grown at Moccasin, Mont., where rust seldom occurs, so that the seed obtained would be uniform and free from shrinkage by rust. Each variety was sown in triplicated rod rows in 1919 and 1920, and in two adjoining rod rows in subsequent years. Sowings were made on two dates in 1919. In Table 1 are listed the stations at which the uniform rust nursery has been grown, the number of varieties grown at each station each year, and the cooperators who supervised the growing of each nursery.

Most of the notes on rust infection have been made by M. N. Levine and the remainder chiefly by E. C. Stakman and other members of the Office of Cereal Investigations engaged in the study of the epidemiology of black stem rust. In 1920 some of the rust

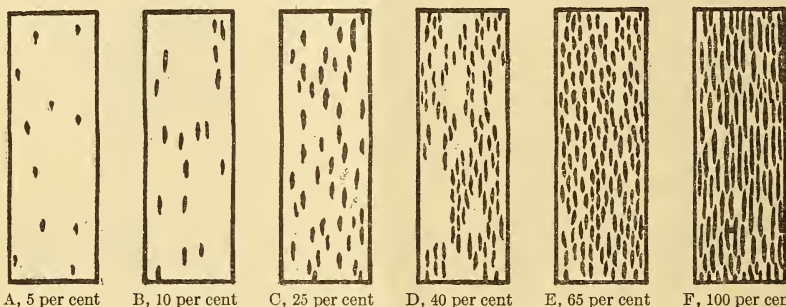


FIG. 1.—Scale for estimating rust, illustrating six degrees of rustiness used in estimating the percentage of stem-rust infection. The shaded spots represent rust, and the figures represent approximately the rust percentages computed on the basis of the maximum of surface covered by rust as shown in the 100 per cent figure (F). Figure F in the diagram represents 37 per cent of actual rust-covered surface and is arbitrarily selected as 100 per cent. The other percentages are in terms of Figure F

notes were taken by the local cooperators. A few of the estimates in other years were made by the local cooperators or by the writers. The detailed notes taken at each station each year, together with data on the physiologic forms present and the ecological factors influencing rust infection, are being published by Levine.⁵ Except in the plant-pathology nursery at St. Paul, Minn., previously mentioned, the rust which occurred resulted from natural infection in the field by whatever physiologic forms of rust were present each season. References to the relative susceptibility or resistance of wheat varieties therefore refer to their reaction in the field just before maturity.

RESULTS OBTAINED

The percentages of rust infection of each variety at each station and the average infection of each variety for each year are shown in Tables 2 to 7, inclusive. The percentages of infection are based on the scale shown in Figure 1. When a variety was not grown at all

⁵ Levine, M. N. Statistical studies on the variation of physiologic forms of *Puccinia graminis tritici* and the effect of ecological factors on the susceptibility of wheat varieties. Unpublished thesis, Univ. Minn., Dec., 1924.

stations, or when the annual average was not comparable with the other varieties, the fact is noted. Following the presentation of the data by years, average rust infections for all varieties during the entire period are shown in Table 8, together with a comparison with the standard variety, Marquis, during the same station years.

RESULTS IN 1919

Data on rust infection were obtained from 13 stations in 1919. Owing to severe drought at Dickinson, N. Dak., only a trace of rust was observed, and that was confined to three varieties. The average infection for the season varied from a trace on Khapli emmer to 65 per cent or more on Haynes Bluestem and Preston. Acme, Monad, and Pentad showed the lowest infection of the durum wheats and Kota the lowest of the hard red spring wheats. Two varieties of emmer have been extremely resistant to rust throughout the experiments. The data are presented in Table 2.

TABLE 2.—Percentage of stem-rust infection of 20 varieties of wheat and emmer grown in uniform nursery experiments to determine their susceptibility to stem rust at 13 experiment stations in the United States in 1919

[T=trace]

Class and variety	C. I. No.	Stem-rust infection (per cent)											Average		
		Prairie (subhumid)						Great Plains (semiarid)							
		St. Paul, Minn.	Fargo, N. Dak.	Brookings, S. Dak.	Lincoln, Nebr.	Ames, Iowa	Manhattan, Kans.	North Dakota		South Dakota		Archer, Wyo.		Akron, Colo.	Amarillo, Tex.
								Man- dan	Dickin- son	Hig- hmore	Newell				
Durum:															
Kubanka	1440	^a T	15	40	15	9	25	^a 7	0	25	5	15	10	10	13.5
Do	2094	^a T	15	25	5	T	15	^a 3	0	65	5	25	8	2	12.9
Do	4063	^a T	40	65	65	7	(^d)10	0	0	65	5	33	10	10	^e 25.8
Arnautka	4064	65	60	65	50	20	30	15	0	65	5	40	8	15	33.7
Do	6236	^a T	40	65	25	20	40	20	T	80	^b 25	50	8	10	29.5
Mindum	5296	^a T	25	^c 55	5	6	25	15	T	25	^b 5	65	^a 2	2	17.7
Acme	5284	T	10	0	2	3	T	7	0	5	^b 20	10	5	T	4.8
Monad	3320	^b 5	10	0	3	3	5	5	0	5	5	10	T	T	4.0
Pentad	3322	0	0	0	T	T	5	T	0	0	5	5	0	0	1.2
Hard red spring:															
Haynes Bluestem	2874	50	100	100	100	75	90	40	0	100	40	65	35	65	66.2
Marquis	3641	40	100	85	85	75	70	25	0	70	50	65	15	65	57.3
Power	3697	60	100	100	90	65	80	37	0	95	40	65	15	55	61.7
Ruby	6047	25	100	100	65	35	(^d)15	0	20	65	10	20	70	70	^f 38.6
Preston	3081	50	100	95	90	65	90	43	0	90	40	65	25	70	65.6
Kota	5878	0	10	5	^c 5	T	T	T	0	T	5	10	T	1	2.8
Prelude	4323	T	100	65	5	(^d)10	0	15	25	5	15	60	10	40	^f 27.3
Kubanka × Haynes Bluestem	4783	30	100	100	50	40	60	20	T	40	50	35	10	40	44.2
Kubanka × Preston	4789	30	100	100	40	20	70	15	0	25	65	50	10	25	42.3
Emmer:															
Vernal	3686	0	0	0	T	T	T	0	1	2	^b 25	T	0	0	2.2
Khapli	4013	T	---	0	0	0	(^d)0	0	0	1	0	5	T	0	^f .5

^a Few but normal pustules.^b Mostly leaf-rust infection.^c Glumes and awns rusted.^d Harvested before rust notes were taken.^e Average of only 12 nurseries.^f Average of only 11 nurseries.

RESULTS IN 1920

In 1920 the rust nursery consisted of 20 varieties grown at 16 experiment stations. Eight of these stations were located in western Canada, and the data from these were supplied by W. P. Fraser, of

the Dominion department of botany. The average infection of all varieties was much higher this season than in 1919. The two varieties of emmer were again nearly immune from rust. As in 1919, the lowest percentages of rust developed on Pentad, Acme, Monad, and Kota. The percentages of infection observed are shown in Table 3.

TABLE 3.—Percentage of stem-rust infection of 20 varieties of spring wheat and emmer grown in uniform nursery experiments to determine their susceptibility to stem rust at 16 experiment stations in the United States and Canada in 1920

[T=Trace]

Class and variety	Stem-rust infection (per cent)																	
	United States										Canada							
	C. I. No.	Prairie (subhumid)			Great Plains (semiarid)				Manitoba		Saskatchewan			Edmonton, Alberta	Average			
		St. Paul, Minn. ^a	Fargo, N. Dak.	Lincoln, Nebr.	Man-dan	Dick-inson	North Dakota	Highmore, S. Dak.	Archer, Wyo.	Akron, Colo.	Morden	Winnipeg	Brandon			Indian Head	Saskatoon	Rosthern
Durum:																		
Kubanka	1440	95	15	5	15	10	5	25	45	25	40	40	40	30	35	2	8	27.2
Do.	2094	100	15	10	15	6	5	25	35	25	40	50	35	30	40	2	10	27.7
Do.	4063	95	15	5	20	7	5	25	40	30	40	40	40	30	45	3	10	28.1
Arnautka	4064	95	40	5	25	14	5	50	40	35	50	50	35	30	40	1	10	32.8
Do.	6236	95	40	5	20	8	5	50	35	35	50	50	40	30	35	1	10	31.8
Mindum	5296	95	25	5	15	7	5	25	28	35	50	50	35	10	10	0	2	24.8
Acme	5284	25	10	4	1	3	T	5	10	7	25	30	25	7	7	0	1	10.0
Monad	3320	25	0	4	1	5	T	5	15	7	25	25	25	7	7	1	1	9.6
Pentad	3322	30	0	4	0	1	T	5	1	1	3	3	3	3	1	0	0	3.4
Hard red spring:																		
Haynes Bluestem	2874	100	100	33	80	22	40	50	65	50	65	65	55	40	75	15	25	55.0
Marquis	3641	100	65	23	65	16	25	40	50	50	50	50	50	25	25	10	15	41.2
Power	3697	100	100	25	65	17	20	50	60	50	60	65	60	40	40	8	15	47.2
Ruby	6047	85	40	40	35	15	10	50	35	50	65	65	65	40	35	15	8	40.8
Preston	3081	100	100	33	75	20	40	50	65	65	75	65	65	35	35	20	25	54.3
Kota	5878	40	10	4	T	1	5	25	15	40	40	50	35	1	3	1	1	16.9
Prelude	4323	95	40	40	25	19	10	40	40	50	55	65	55	35	35	20	8	39.5
Kubanka X Haynes Bluestem	4788	95	100	5	40	17	40	25	35	40	55	50	65	40	50	8	8	42.1
Kubanka X Preston	4789	100	100	4	40	13	40	40	35	50	65	65	65	35	40	8	8	44.3
Emmer:																		
Vernal	3686	15	0	2	0	T	T	0	T	2	2	3	1	0	1	1	0	1.7
Khaphi	4013	5	0	0	0	T	T	0	0	1	1	1	1	1	1	1	1	.8

^a Nursery inoculated with spores of several biologic forms found in Minnesota.
^b Not grown, percentage of rust estimated from Kubanka (C. I. 1440).
^c Not grown, percentage of rust estimated from Arnautka (C. I. 4064).
^d Not grown, percentage of rust estimated from Power (C. I. 3697).

RESULTS IN 1921

In 1921 the rust nursery was sown at 14 stations in the United States and at 10 stations in Canada. The data from Canada were again furnished by Fraser. At St. Paul, Minn., as previously noted, two sowings were made, one in the agronomy nursery, which was not inoculated, and the other in the rust nursery, where the wheat plants were sprayed with a suspension of spores of several physiologic forms of stem rust. In 1921 the nursery included 24 varieties, but not all of the varieties were sown at Golden Valley and Duluth, Minn. Rust infection was recorded at all stations except Edmonton and Lacombe, Alberta, and at several of the stations the infection

was rather heavy. Traces only of rust were found at Akron, Colo., Scott, Saskatchewan, and Vermilion, Alberta. The percentages of infection on Pentad, Acme, Monad, and Kota wheats and the two varieties of emmer were again low. The data obtained in 1921 are shown in Table 4.

TABLE 4.—Percentage of stem-rust infection of 24 varieties of spring wheat and emmer grown in uniform nursery experiments to determine their susceptibility to stem rust at 24 experiment stations in the United States and Canada in 1921

[T=Trace]

Class and variety	Stem-rust infection (per cent)																				Average								
	United States																			Canada									
	Prairie (subhumid)												Great Plains (semiarid)			Mani- toba	Saskatch- ewan	Alber- ta											
	Minnesota					Wis. Duluth ^a	Wis. Madison	N. Dak. Fargo	S. Dak. Brookings	North Dakota																			
	C. I. No.	Rust nur- sery	Agronomy nursery	Crockston	Morris					Golden Valley ^a	Langdon	Edgley	Mandan	Dickinson	Akron, Colo.				Winnipeg			Brandon	Indian Head	Saskatoon	Rosthern	Scott	Vermilion	Edmonton	Lacombe
Durum:																													
Kubanka	1440	b T	0	50	2	...	25	45	25	20	20	45	20	45	5	T	0	60	40	50	3	5	15	0	0	0	0	0	17.8
Do	2094	b T	0	50	2	0	15	20	40	20	10	7	25	2	0	T	0	50	35	60	2	10	15	0	0	0	0	0	14.6
Do	4063	0	60	2	T	...	25	45	28	15	18	45	20	32	5	2	0	70	45	45	20	20	25	0	0	0	0	0	20.5
Arnautka	1493	30	0	70	5	2	55	30	60	33	15	20	32	5	2	0	0	70	40	35	15	8	30	0	0	0	0	0	22.3
Do	4064	40	0	65	5	T	...	30	75	40	10	18	40	3	2	0	0	75	55	40	10	25	40	T	0	0	0	0	23.9
Do	6236	b T	0	45	5	...	28	75	40	18	18	40	5	2	0	0	0	75	40	45	20	20	25	0	0	0	0	0	21.8
Mindum	5296	b T	b T	25	T	0	10	28	80	35	18	18	35	1	5	0	0	75	35	35	5	5	10	0	0	0	0	0	16.8
Acme	5284	0	0	2	T	T	T	T	15	12	0	2	5	T	5	0	0	30	4	3	0	1	1	0	0	0	0	0	3.2
Monad	3320	0	0	2	T	0	T	2	10	15	0	3	3	0	0	0	0	25	3	5	0	T	1	0	0	0	0	0	2.8
Pentad	3322	0	0	2	0	T	T	2	10	12	0	2	0	0	0	0	0	3	0	1	0	T	0	0	0	0	0	0	1.4
Kahla	5529	f 25	T	60	T	0	...	60	95	50	20	35	95	3	10	0	0	55	40	30	20	10	30	0	0	0	0	0	26.6
Peliss	1584	f 65	T	55	2	...	70	75	40	20	50	70	T	5	0	0	0	30	35	20	20	10	20	0	0	0	0	0	25.5
Hard red spring:																													
Haynes Bluestem	2874	50	T	85	75	5	50	90	95	55	40	25	70	10	12	0	0	80	60	50	80	5	80	0	0	0	0	0	40.7
Marquis	3641	40	T	90	40	10	55	85	90	50	28	25	85	8	5	T	0	65	90	70	45	60	85	0	0	0	0	0	41.0
Power	3697	55	25	85	15	...	70	100	55	30	25	25	75	6	5	0	0	75	70	40	10	30	80	T	0	0	0	0	37.0
Ruby	6047	30	T	60	3	5	50	70	35	30	25	25	55	1	T	0	0	(*)	90	50	60	50	75	0	0	0	0	0	29.8
Kitchener	4500	80	20	95	50	...	80	85	50	40	40	80	15	12	0	0	0	65	90	45	45	70	75	T	T	0	0	0	45.1
Red Bobs	6255	40	f 15	98	40	...	60	75	65	35	35	25	65	3	2	0	0	(*)	85	35	40	50	60	0	0	0	0	0	36.0
Preston	3081	45	f 20	90	40	...	55	80	95	40	35	25	75	8	3	0	0	80	85	40	35	50	75	T	0	0	0	0	40.7
Kota	5878	T	0	2	15	0	T	T	5	5	5	1	T	0	T	0	0	8	3	5	5	0	5	0	0	0	0	0	2.4
Prelude	4323	40	10	15	10	...	60	f 40	15	20	(*)	65	0	T	0	0	0	(*)	70	40	60	40	50	0	0	0	0	0	25.5
Club:																													
Little Club	4066	40	f 25	60	60	5	...	f 70	100	30	50	35	85	25	5	0	0	40	50	10	5	30	85	0	0	0	0	0	33.8
Emmer:																													
Vernal	3686	0	0	2	2	0	0	5	0	0	0	0	0	0	T	0	0	0	0	0	0	0	0	0	0	0	0	0	.4
Khapli	4013	0	0	0	T	0	...	0	0	0	0	(*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

a Not all varieties were sown.
 b Few but normal pustules.
 c Average of only 23 nurseries.
 d Average of only 24 nurseries.
 e Mostly on immature plants.
 f Infection not uniform.
 g Plants dead ripe.
 h Destroyed by gophers and sparrows.
 i Many plants destroyed by gophers and sparrows.
 j Average of only 21 nurseries.

RESULTS IN 1922

The uniform nurseries were sown at 19 experiment stations in the United States in 1922 and consisted of 22 varieties of wheat and emmer. Not all varieties were sown at Coon Creek and Duluth, Minn. More than a trace of rust was recorded at all stations, and there was heavy infection at most of them.

The varieties Pentad, Monad, Acme, and Kota, as well as the varieties of emmer, continued to show resistance. Owing to its early maturity, which enabled it partly to escape the rust, Prelude had an average infection of only 15.4 per cent. The data are shown in Table 5.

TABLE 5.—Percentage of stem-rust infection of 22 varieties of wheat and emmer grown in uniform nursery experiments to determine their susceptibility to stem rust at 19 experiment stations in the United States in 1922

[T=trace]

Class and variety	Stem-rust infection (per cent)																					
	Prairie (subhumid)											Great Plains (semiarid)										
	Minnesota											North Dakota										
	C. I. No.	St. Paul		Crookston	Morris	Waseca	Coon Creek ^a	Duluth ^a	Chatham, Mich.	Madison, Wis.	Fargo, N. Dak.	Brookings, S. Dak.	Lincoln, Nebr.	Ames, Iowa	Langdon	Edgeley	Mandan	Dickinson	Redfield, S. Dak.	Acher, Wyo. ^b	Akron, Colo.	Average
		Rust nursery	Agronomy nursery																			
Durum:																						
Kubanka	1440	45	25	65	25	40	---	40	45	95	65	25	35	18	20	25	25	45	5	T	35.7	
Do	4063	45	25	65	20	55	---	60	45	92	70	60	30	18	25	25	25	45	0	T	39.5	
Arnautka	1493	40	25	65	20	60	---	40	45	92	80	60	15	12	20	35	20	40	0	T	37.5	
Do	4064	40	25	65	25	60	25	12	45	92	90	60	12	12	25	45	40	55	0	T	38.6	
Mindum	5296	50	25	55	18	50	15	28	45	100	85	75	12	10	25	25	20	25	0	T	35.4	
Acme	5284	T	T	10	2	1	0	0	12	5	15	12	0	T	2	3	5	0	0	T	36.6	
Monad	3320	T	T	10	7	T	0	0	12	5	15	12	0	T	T	7	5	7	0	T	44.5	
Pentad	3322	0	T	10	12	5	T	1	0	12	5	15	12	0	T	10	7	7	0	0	4.8	
Kahla	5529	70	50	75	35	85	3	60	4	100	85	85	30	25	20	25	20	65	0	T	44.1	
Peliss	1584	50	40	75	25	75	20	25	4	90	45	45	20	12	18	15	25	45	T	0	43.2	
Hard red spring:																						
Haynes Bluestem	2874	80	60	90	60	95	25	68	15	45	100	95	60	35	50	35	75	80	0	2	57.3	
Marquis	3641	80	50	90	30	95	25	80	45	4	98	65	30	35	40	45	55	80	0	T	49.4	
Power	3697	85	60	90	50	95	---	25	20	98	75	40	30	45	40	75	80	80	T	5	55.2	
Ruby	6047	85	50	90	45	75	---	18	50	4	90	60	20	25	50	20	30	70	12	3	42.4	
Kitchener	4800	75	50	90	50	80	25	25	20	95	65	20	35	60	35	40	95	45	T	12	48.3	
Red Bobs	6255	80	50	90	55	75	30	35	20	95	65	15	35	55	30	40	80	18	T	12	46.4	
Preston	3081	85	65	90	75	75	40	60	20	95	90	25	45	65	25	70	80	55	T	15	54.8	
Kota	5878	2	T	5	15	8	5	18	0	5	35	12	5	T	T	15	20	3	1	7	7.8	
Prelude	4323	3	5	10	15	15	25	7	25	4	45	40	T	T	35	5	3	25	3	1	T	41.4
Club:																						
Little Club	4066	65	45	90	85	75	60	---	8	30	75	65	30	T	90	35	95	95	35	5	25	45.1
Emmer:																						
Vernal	3686	T	0	0	T	T	0	3	0	0	T	T	0	T	0	0	T	3	0	T	0	.3
Khapli	4013	0	0	0	0	T	0	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0

^a Not all varieties were sown.

^b About a month later the rust on Kubanka 1440 developed to 15 per cent, on Power to 30 per cent, and on Little Club to 25 per cent.

^c Average of only 18 nurseries.

^d Average of only 19 nurseries.

^e Few but normal pustules.

^f Pustules minute.

RESULTS IN 1923

In 1923 the uniform rust nursery, consisting of 24 varieties, was sown at 19 experiment stations in the United States. At Coon Creek, Minn., the wheats were sown both on sandy land and on a peat bog. As in 1921 and 1922, two nurseries were sown at St. Paul, one being sprayed with spores of several physiologic forms and the other allowed to become infected naturally. There was rather heavy

infection at all stations. The varieties were in about the same relative position in average rust infection as in previous seasons. The results obtained in 1923 are presented in Table 6.

TABLE 6.—Percentage of stem-rust infection of 24 varieties of spring wheat and emmer grown in uniform nursery experiments to determine their susceptibility to stem rust at 19 experiment stations in the United States in 1923

[T=trace]

Class and variety	Stem-rust infection (per cent)																		Average						
	Prairie (subhumid)												Great Plains (semiarid)												
	Minnesota												North Dakota												
	C. I. No.	Rust nursery	Agromony nursery	St. Paul	Crookston	Morris	Waseca	Sandy hill	Peat bog	Duluth	Chatham, Mich.	Madison, Wis.	Fargo, N. Dak.	Brookings, S. Dak.	Lincoln, Nebr.	Ames, Iowa	Langdon	Edgely		Mandan	Dickinson	Redfield, S. Dak.	Archer, Wyo.	Akron, Colo.	
Durum:																									
Kubanka	1440	15	12	30	30	20	5	20	35	20	18	25	35	12	25	20	17	12	18	25	35	30	21.9		
Do.	2094	12	8	25	15	10	8	20	40	20	5	30	45	5	20	25	22	12	25	20	30	30	20.3		
Do.	4063	15	12	30	15	12	8	25	45	23	12	35	50	17	30	30	25	10	20	25	35	35	23.9		
Arnautka	1493	12	12	18	25	15	10	35	45	20	15	45	40	10	25	25	25	15	20	15	25	30	22.7		
Do.	4064	15	20	25	30	15	10	30	50	25	10	45	40	10	30	35	30	18	25	20	35	25	25.5		
Do.	6236	12	15	32	25	18	10	45	50	35	18	45	35	5	35	30	35	18	25	20	35	25	27.2		
Mindum	5296	5	10	25	20	10	8	40	40	30	15	45	40	5	25	30	20	18	25	18	40	20	23.4		
Acme	5284	T	T	T	T	T	T	T	T	T	T	T	T	T	8	8	0	T	T	1	5	8	10	2.7	
Acme	3320	1	1	T	5	0	2	T	T	T	T	T	T	0	0	0	2	T	T	2	3	6	10	2.6	
Pentad	3322	T	T	5	T	0	0	T	T	T	0	T	18	0	8	8	T	T	T	T	4	8	8	2.0	
Kahla	5529	18	25	40	30	15	10	20	65	35	25	25	40	8	85	30	50	25	15	25	50	50	32.7		
Peliss	1584	18	18	45	30	5	10	20	25	45	18	45	40	12	70	30	40	25	20	18	40	30	28.8		
Hard red spring:																									
Haynes Bluestem	2874	25	25	70	95	35	25	90	65	30	40	75	70	12	75	90	90	40	75	55	35	40	55.1		
Marquis	3641	30	35	40	90	35	25	95	80	25	45	70	15	75	85	80	30	20	50	50	40	51.7			
Power	3697	35	25	60	95	45	25	95	90	20	50	80	70	15	75	90	85	50	75	55	50	45	58.6		
Ruby	6047	35	20	50	90	30	15	98	45	50	65	65	55	10	70	80	70	40	15	45	55	35	49.4		
Kitchener	4500	45	40	50	90	70	20	95	50	45	75	75	60	15	65	80	75	40	20	55	60	45	55.7		
Red Bobs	6255	40	30	55	90	50	18	95	40	60	75	75	60	8	55	85	80	45	18	50	60	45	54.0		
Preston	3081	45	30	60	95	50	25	98	60	40	70	80	75	10	75	98	85	55	75	60	50	60	51.2		
Kota	5878	2	5	8	40	1	T	15	10	12	8	35	60	T	5	15	5	15	10	25	35	20	15.5		
Prelude	4323	35	12	60	50	15	10	95	60	50	60	30	45	3	25	35	65	15	40	20	55	25	38.3		
Club:																									
Little Club	4066	45	50	75	90	70	25	85	50	15	70	35	75	12	25	95	80	55	55	50	60	50	55.6		
Emmer:																									
Vernal	3686	T	0	T	0	0	0	0	T	0	0	0	T	0	0	0	0	0	0	0	0	0	0	0	
Khapli	4013	0	0	1	0	0	0	0	2	0	0	0	T	1	0	0	0	T	0	1	0	T	0	.2	

RESULTS IN 1924

The rust nursery was grown at 22 experiment stations in 1924. At the four stations in Texas, the wheats were sown in the fall of 1923. In the spring of 1924 several varieties which had been grown previously were omitted, and a few new varieties were added. The nurseries sown in Texas therefore differed somewhat from those sown at the northern stations. A trace or more of rust was observed at all stations. Most of the common-wheat varieties were heavily infected at nearly all stations. The infection on the durum varieties was unusually light.

Of the new varieties added to the test, Marquillo, Progress, Kota X Marquis, and Reliance were more rust resistant than Marquis, Power, Haynes Bluestem, and Preston. Owing to its earlier maturity, Quality was somewhat rust escaping. The data obtained are shown in Table 7.

TABLE 7.—Percentage of stem-rust infection of 31 varieties of spring wheat and emmer grown in uniform nursery experiments to determine their susceptibility to stem rust at 22 experiment stations in the United States in 1924

[T = trace]

Class and variety	Stem-rust infection (per cent)																										
	Prairie (subhumid)											Great Plains (semiarid)					South-west										
	Minnesota											North Dakota					Texas										
	C. I. No.	St. Paul	Agronomy nursery		Crookston	Waseca	Coon Creek peat bog ^b	Duluth	Chatham, Mich.	Madison, Wis.	Fargo, N. Dak.	Brookings, S. Dak.	Lincoln, Nebr.	Ames, Iowa	Langdon	Edgeley	Mandan	Dickinson	Redfield, S. Dak.	North Platte, Nebr.	Archer, Wyo.	College Station ^c	Denton ^d	Temple ^e	Angleton ^d	Average	
		Rust nursery ^a																									
Durum:																											
Kubanka	1440	2	T	15	10	—	T	3	5	35	25	10	T	1	5	T	1	T	0	10	30	—	25	T	3	8.6	
Do	2094	2	T	15	10	—	—	1	5	T	15	15	T	2	1	T	1	0	5	5	40	—	25	T	3	7.1	
Do	4063	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.0	
Nodak	6519	T	T	3	10	—	0	3	0	15	20	10	T	1	1	1	T	0	5	25	—	—	—	—	—	4.9	
Arnautka	1493	5	T	8	15	—	T	8	10	25	25	20	T	8	6	1	3	0	12	28	—	—	—	—	—	9.0	
Do	4064	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.3	
Do	6236	15	T	12	15	—	3	12	5	25	30	30	5	6	1	T	5	0	10	45	—	—	—	—	—	12.2	
Do	6881	15	T	10	20	—	T	10	12	20	20	25	3	8	3	1	3	T	18	50	—	—	—	—	—	12.1	
Mindum	5296	25	T	10	20	—	2	8	5	25	30	20	T	4	2	2	3	0	10	38	15	3	0	T	—	10.1	
Aeme	5284	0	0	1	T	—	0	0	0	0	2	0	0	T	T	T	T	0	3	20	T	T	0	0	—	1.3	
Monad	3320	0	0	2	T	—	0	0	0	0	2	0	0	T	T	T	T	0	2	10	T	T	0	0	—	1.8	
Pentad	3322	T	0	T	2	0	0	0	0	2	T	0	0	T	T	T	T	0	3	15	0	T	0	0	—	1.0	
Kahla	5529	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	7	2	5	4.8	
Peliss	1584	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35	5	1	10	—	12.8	
Hard red spring:																											
Haynes Bluestem	2874	35	3	95	75	—	15	15	15	75	95	45	5	30	10	23	25	0	40	50	—	15	2	20	—	32.8	
Marquis	3641	40	T	95	60	—	20	18	25	65	70	45	5	55	10	25	25	T	40	75	40	25	3	20	—	34.6	
Power	3697	35	3	95	45	—	25	18	12	85	80	45	2	50	8	25	27	T	45	70	—	30	10	30	—	35.2	
Ruby	6047	25	T	90	35	40	12	5	30	60	65	50	T	65	3	25	25	T	25	70	—	35	1	8	—	30.4	
Kitchener	4800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35	8	20	—	21.0	
Red Bobs	6255	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35	5	18	—	19.3	
Marquillo	6887	12	T	50	10	—	3	3	2	T	25	15	8	2	45	15	0	8	25	—	—	—	—	—	—	12.0	
Preston	3081	65	2	90	65	60	25	35	20	85	75	25	1	150	10	25	27	T	35	60	35	25	1	40	3	37.2	
Kota	5878	3	0	40	5	5	T	T	T	35	5	12	T	25	1	3	5	0	8	35	7	5	T	2	—	8.5	
Prelude	4323	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.3	
Progress	6902	2	T	65	20	30	5	5	T	60	15	20	0	25	T	1	5	0	10	25	—	—	—	—	—	15.2	
Kota X Marquis	6898	2	0	35	5	8	0	2	T	15	8	3	T	20	T	1	3	0	10	15	—	—	—	—	—	16.7	
Reliance	7370	8	0	80	40	—	10	10	8	35	45	20	1	135	1	23	20	0	15	30	—	—	—	—	—	21.2	
White:																											
Quality	6607	12	2	60	35	—	10	20	25	20	60	15	5	45	1	20	25	T	12	50	—	—	—	—	—	—	23.2
Club:																											
Little Club	4066	18	8	90	75	—	40	35	35	85	95	40	5	90	10	65	50	1	20	70	—	20	10	12	—	41.6	
Emmer:																											
Vernal	3686	T	0	T	0	0	0	0	0	0	T	0	0	0	0	0	0	0	0	0	0	T	T	0	0	0	
Khapli	4013	0	0	T	0	T	0	T	0	T	T	T	0	0	T	0	0	0	0	0	1	—	0	0	0	0	

^aArtificially induced epidemic.
^bMissing varieties destroyed by root rots.
^cIncomplete uniform rust nursery.

^d1922 nursery type.
^eAverage of only 21 nurseries.
^fAverage of only 18 nurseries.
^gAverage of only 3 nurseries.

^hAverage of only 22 nurseries.
ⁱAverage of only 4 nurseries.
^jAverage of only 19 nurseries.

SUMMARY OF RESULTS

Spring-wheat rust nurseries have been grown at 39 stations in the United States and Canada during one or more of the six years from 1919 to 1924, inclusive. There were 13 nurseries in 1919, 16 in 1920, 24 in 1921, 19 in 1922, 19 in 1923, and 22 in 1924, or a total of 113 nursery years. The four additional plant-pathology nurseries at St. Paul from 1921 to 1924, inclusive, and the peat-bog nursery at Coon Creek, Minn., make a total of 118 experiments, or nursery years.

TABLE 8.—Average annual percentage of stem-rust infection of the varieties of wheat grown in uniform rust nurseries at 39 experiment stations in the United States and Canada, together with a comparison with Marquis, during one or more of the six years from 1919 to 1924, inclusive

Class and variety	Stem-rust infection (per cent)								Nursery years	Percentage of Marquis	
	C. I. No.	1919	1920	1921	1922	1923	1924	Weighted average*			Marquis, same years
DURUM WHEAT											
Kubanka.....	1440	13.5	27.2	17.8	35.7	21.9	8.6	20.6	45.1	112	45.7
Do.....	2094	12.9	27.7	14.6	-----	20.3	7.1	16.4	45.0	93	36.4
Kubanka No. 8.....	4063	25.8	28.1	20.5	39.5	23.9	11.0	26.6	46.0	94	57.8
Nodak.....	6519	-----	-----	-----	-----	-----	4.9	4.9	34.3	21	14.3
Arnautka.....	1493	-----	-----	22.3	37.5	22.7	9.0	22.3	43.7	85	51.0
Do.....	4064	33.7	32.8	23.9	38.6	25.5	1.3	29.3	46.0	96	63.7
Do.....	6236	29.5	31.8	21.8	-----	27.2	12.2	24.0	45.3	91	53.0
Akrona.....	6881	-----	-----	-----	-----	-----	12.1	12.1	37.4	18	32.4
Mindum.....	5296	17.7	24.8	16.8	35.4	23.4	10.1	21.1	45.0	117	46.9
Acome.....	5284	4.8	10.0	3.2	3.6	2.7	1.3	3.9	44.7	116	8.7
Monad.....	3320	4.0	9.6	2.8	4.5	2.6	.8	3.7	44.7	116	8.3
Pentad.....	3322	1.2	3.4	1.4	4.8	2.0	1.0	2.3	45.0	117	5.1
Peliss.....	1584	-----	-----	25.5	33.2	28.8	12.8	27.9	45.4	67	61.5
Kahla.....	5529	-----	-----	26.6	44.1	32.7	4.8	32.1	44.9	68	71.5
COMMON WHEAT											
Hard red spring:											
Marquis.....	3641	57.3	41.2	41.0	49.4	51.7	34.6	45.0	45.0	117	100.0
Power.....	3697	61.7	47.2	37.0	55.2	58.6	35.2	48.0	45.1	112	106.4
Ruby.....	6047	38.6	40.8	29.8	42.4	49.4	30.4	38.1	44.3	112	86.0
Red Bobs.....	6255	-----	-----	36.0	46.4	54.0	19.3	44.0	45.3	66	97.1
Kitchener.....	4800	-----	-----	45.1	48.3	55.7	21.0	47.4	45.3	66	104.6
Marquillo.....	6887	-----	-----	-----	-----	-----	12.0	12.5	37.4	18	33.4
Haynes Bluestem.....	2874	66.2	55.0	40.7	57.3	55.1	32.8	49.5	45.0	116	110.0
Preston.....	3081	65.6	54.3	40.7	54.8	61.2	37.2	50.6	45.3	116	111.7
Kota.....	5878	2.8	16.9	2.4	7.8	15.5	8.5	8.9	45.0	117	19.8
Kota×Marquis.....	6898	-----	-----	-----	-----	-----	6.7	6.6	37.4	18	17.6
Reliance.....	7370	-----	-----	-----	-----	-----	21.2	21.2	37.4	18	56.7
Progress.....	6902	-----	-----	-----	-----	-----	15.2	14.3	37.4	18	33.2
Kubanka×Haynes Bluestem.....	4788	44.2	42.1	-----	-----	-----	-----	43.0	48.4	29	88.8
Kubanka×Preston.....	4789	42.3	44.3	-----	-----	-----	-----	43.4	48.4	29	89.7
Prelude.....	4323	27.3	39.5	25.5	15.4	38.3	3.3	28.3	45.5	91	62.2
White wheat:											
Quality.....	6607	-----	-----	-----	-----	-----	23.2	23.2	37.4	18	62.0
CLUB WHEAT											
Little Club.....	4066	-----	-----	33.8	53.1	55.6	41.6	45.4	43.3	85	104.8
EMMER											
Vernal.....	3686	2.2	1.7	.4	.3	0	0	.6	45.0	117	1.3
Khapl.....	4013	.5	.8	0	0	.2	0	.2	44.1	111	.5

* Average of all tests in which Marquis was grown.

At least traces of rust were recorded in all nurseries except those at Edmonton and Lacombe, Alberta, in 1921. At Dickinson, N. Dak., in 1919, and at Akron, Colo., Scott, Saskatchewan, and Vermilion,

Alberta, in 1921, the maximum rust infection on any variety was recorded as a trace. Percentage estimates of rust infection were obtained in 107 of the 113 station years during which the nurseries were grown. This fact alone shows the prevalence of stem rust and the necessity for rust investigations in the northern spring-wheat States.

There were severe rust losses in 1919, in 1920, and 1923. In 1921, 1922, and 1924 the injury from rust was less than in the other years and was mostly local. In 1919 and 1921 severe drought inhibited rust development in the Great Plains area. The durum wheats were rather heavily infected as compared with common wheats in 1920 and 1922, but in 1924 the infection on durum wheats was unusually light.

The average percentage of rust infection of each variety, together with a comparison with Marquis for the same station years, is shown in Table 8. It is seen that all varieties of durum wheat have a lower percentage of infection than Marquis and most of the other common wheats. Durum wheats as a class have long been known to be more rust resistant than common wheats. These experiments are confirmatory of earlier knowledge, although the durum varieties were more heavily attacked some years than others. Of the durum wheats the most resistant are Pentad, Monad, and Acme, with average infections of 2.3, 3.7, and 3.9 per cent, respectively. Kubanka (C. I. No. 1440) is only slightly more resistant than Mindum on the average, although the latter variety usually is more resistant in Minnesota. Kubanka (C. I. No. 2094) had an average infection of 16.4 per cent, while Kubanka (C. I. No. 1440) had 20.6 per cent. Nodak was included in the experiments only in 1924, during which it had an average rust infection of 14.3 per cent of that of Marquis. Arnautka, Peliss, and Kahla are more susceptible to rust than Kubanka (C. I. No. 1440).

Power, Kitchener, Haynes Bluestem, and Preston, all hard red spring wheats, and Little Club, a club wheat, all have a higher average rust infection than Marquis. These varieties also mature later than Marquis.

Several of the common wheats have a lower percentage of infection than Marquis. Of these Kota, Kota \times Marquis (C. I. No. 6898), Reliance, Marquillo, and Progress are more resistant than Marquis. The common wheats, other than those specifically named, which have a lower infection than Marquis, mature earlier and partly escape rust infection and injury. Kota is the most resistant common wheat grown during more than one year and has an average infection of only 8.9 per cent. Excluding the resistant varieties mentioned above, the relative infections of the varieties of common wheat and of Little Club are practically in the order of their average dates of maturity. The ability of the early wheats partly to escape rust during most seasons is due to their being past the most susceptible stage before the maximum inoculum is present and because the plant tissues become hard and dry before the maximum development of the fungus is reached.

Little Club matures late and also is susceptible to all physiologic forms of stem rust; consequently it shows heavy infection. The two varieties of spring emmer, Vernal and Khapli, are nearly immune to stem rust, the first under field conditions and the latter even in

the greenhouse. They have never shown injury from stem rust under field conditions in the region where spring emmer is grown.

Figure 2 illustrates the average infection of the varieties grown during the entire six years.

RESISTANT VARIETIES

The reduction of losses from stem rust of wheat by the growing of resistant varieties is a certain and feasible method, as shown by the slight susceptibility of certain wheats, but has been restricted in its application by the limited agronomic or commercial value of the existing resistant varieties. The production of high-yielding and high-quality resistant varieties is therefore a real challenge to the cereal breeder.

As noted, Vernal and Khapli emmer have not been injured by rust when sown in the field in the Northern States. Emmer is not commercially valuable, as it can not be used for making bread or macaroni and is less productive than adapted varieties of wheat, oats, and

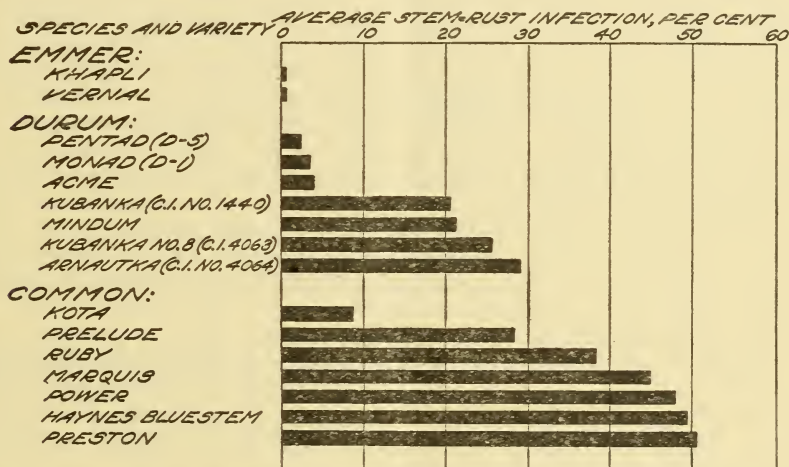


Fig. 2.—Diagram showing the average stem-rust infection of varieties of emmer and durum and common wheats grown at experiment stations during each of the six years from 1919 to 1924, inclusive

barley. The growing of this crop therefore offers little toward reducing rust losses. Pentad, Monad, and Acme wheats have rarely if ever been injured by stem rust in those localities where they are adapted. During very severe rust epidemics these varieties out-yield all other wheats. Unfortunately, these are durum wheats, for which there is only a limited market in this country. In addition, the macaroni made from Pentad, Monad, and Acme, especially Pentad, usually is grayish in color, which is not desired by the trade. These three varieties therefore have a lower market value than the other durum wheats. Even at low prices, however, the Acme, Monad, and Pentad wheats are more profitable than others during seasons of severe rust. On the other hand, an increased production of these varieties would still further depress their market value. Kubanka rusts less on the average than other commercial durum varieties, except the three just mentioned and Nodak. Because of its good yields and quality it should be grown instead of Arnautka,

Peliss, and Kahla. The Nodak variety, a selection from Kubanka, has recently been distributed in North Dakota, where it probably should eventually replace the other durum wheats. It not only is equal or superior to Kubanka in yield and quality, but is much more rust resistant.

Marquis escapes rust injury slightly better than Haynes Bluestem, Power, and Preston. Because of this better rust escapement and the higher yields and quality of Marquis, the other varieties should be largely discontinued from cultivation. The almost complete elimination of Haynes Bluestem from the farms in this country has reduced rust losses considerably.

The varieties Quality, Ruby, Red Bobs, and Prelude, because of their earlier maturity, show a lower rust infection than Marquis. In spite of their being rusted less than Marquis, these early varieties on the average are less productive than the latter variety. This indicates that nonresistant varieties of wheat earlier than Marquis are not a likely means of reducing rust losses in Minnesota and the Dakotas.

Of the resistant varieties, Progress is weak in gluten, and Marquillo, the Marquis \times Iumillo hybrid, produces a yellowish bread. Therefore these varieties can not be expected to solve the rust problem in themselves. Reliance, the Kanred \times Marquis hybrid, is only partly resistant to rust under field conditions, although it yields well when rust is present. The Kota variety is ordinarily decidedly resistant to stem rust in the field. It has outyielded all other common-wheat varieties in North Dakota and South Dakota and is equal to Marquis in milling and baking quality. However, it is susceptible to leaf rust, bunt, and loose smut, and lodges badly on rich or wet soil. In Minnesota, Kota usually yields less than Marquis. Hybrids between Marquis and Kota now being tested promise to exceed Kota in yield, quality, and rust resistance.

Summarizing the relation of resistant varieties to stem-rust control, the following recommendations are made: In Minnesota Marquis should be grown because it escapes rust slightly better than Haynes Bluestem, Red Fife, and Preston and usually is more productive than Kota. Under conditions of severe rust, where a durum wheat is desired, Mindum should be sown.

In North Dakota and South Dakota Kubanka or Nodak should be substituted for other durum wheats now grown. Except on rich or wet soils and in northwestern North Dakota, Kota should replace Marquis to a considerable extent. In Minnesota, the Dakotas, and Montana, except in limited sections, Marquis or Kota should be grown instead of Haynes Bluestem, Red Fife, Power, Preston, Ruby, Red Bobs, Prelude, and Quality. Pentad, the red-kerneled durum wheat, should not be grown, because of its low market value. In spite of their extreme rust resistance, Acme and Monad should not be grown in more than limited quantities. Quality should not be grown because it usually yields less, is not rust resistant, and shatters more than Marquis. This is a white wheat, and to grow it would result in the further mixing of wheat classes and in a lower grade and price for all wheat.

DESCRIPTIONS OF VARIETIES

Brief descriptions and histories of the rust-resistant and important commercial durum and common wheat varieties are here given. Most of the varieties have been described more fully by Clark, Martin, and Ball,⁶ and Clark and Martin.⁷

DURUM WHEATS

Kubanka (C. I. No. 1440).—Kubanka wheat has smooth yellowish chaff, yellowish beards, and large white (amber) kernels. The heads are thick and compact and nod slightly at maturity. This variety showed an average stem-rust infection of 20.6 per cent. Nodak, which was selected from Kubanka, is very resistant to stem rust.

This strain of Kubanka (S. P. I. No. 5639) was introduced into this country in 1900 by M. A. Carleton, cerealist of the Department of Agriculture, from the Uralsk Government in Russia. The seed was increased and distributed by the Department of Agriculture and the North Dakota and South Dakota Agricultural Experiment Stations.

Kubanka (C. I. No. 2094).—This strain of Kubanka differs from the preceding in having shorter stems and more compact spikes. It was introduced from Uralsk, Russia, by the United States Department of Agriculture in 1902. It is more rust resistant than Kubanka (C. I. No. 1440) but is less productive.

Mindum.—The Mindum variety differs from Kubanka in having longer stems, spikes, awns, and beaks, and a shorter brush on the kernels. It also is more nodding. Mindum is nearly as rust resistant as Kubanka (C. I. No. 1440). Mindum was first found as a mixture in a field of common wheat at the Minnesota Agricultural Experiment Station in 1896. After further selection and considerable testing it was distributed to Minnesota farms in 1917.

Acme.—The Acme variety has shorter stems, spikes, and kernels than Kubanka and is much more resistant to stem rust. The spikes of Acme also are smaller and not so thick as those of Kubanka. The kernels of Acme are midsized, pointed at the germ end, blunt at the brush end, and have a somewhat boat-shaped appearance or outline. Acme lodges easily under humid conditions. It is highly resistant to stem rust and has seldom, if ever, suffered injury from that disease.

Acme was selected from Kubanka (C. I. No. 1516) at the Highmore (S. Dak.) substation in 1909, and after its high-yielding power had been determined seed was distributed from the Highmore substation in 1916 by the South Dakota Agricultural Experiment Station. Although it was distributed in the spring of 1916, its rust resistance was not known until later in that season, when rust appeared in destructive abundance. This resistance to rust, together with its high yields, caused the variety to become popular.

Monad.—The Monad, or D-1 (Durum No. 1), variety is similar to Acme in appearance. The size, shape, and color of the heads and kernels of the two varieties are almost identical, and they are equally resistant to stem rust. Monad is not quite so easily lodged as Acme.

⁶ Clark, J. A., Martin, J. H., and Ball, C. R. Classification of American wheat varieties. U. S. Dept. Agr. Bul. 1074, 238 pp., illus. 1922.

⁷ Clark, J. A., and Martin, J. H. The hard red spring wheats. U. S. Dept. Agr. Bul. 1281, 28 pp., illus. 1922.

———. The durum wheats. U. S. Dept. Agr. Bul. 1304, 15 pp., illus. 1923.

The Monad variety was obtained in the Saratov Government, Russia, in 1903, by Prof. H. L. Bolley, of the North Dakota Agricultural College. During the rust epidemics of 1915 and 1916 the extreme resistance of Monad was strikingly apparent. Because of this and its high yield, seed of this variety has been increased and distributed in recent years by the North Dakota Agricultural Experiment Station.

Pentad.—Pentad, or D-5, has chaff and beards nearly white, instead of the usually yellow or brownish color characteristic of the durum varieties just described. The heads are more slender and less compact than those of the other durum varieties grown in this country. The kernels are short, boat shaped, pointed at the germ end, blunt at the tip end, and dull red in color. The plants are of medium height and are less easily lodged than those of Acme and Monad. Pentad is the most resistant to stem rust of any variety of wheat grown commercially in the United States.

Pentad was introduced from Russia in 1903 by Prof. H. L. Bolley, of the North Dakota Agricultural Experiment Station. It was first distributed from that station in 1911. It since has become rather widely grown, especially in North Dakota, on account of its extreme rust resistance.

Nodak.—The Nodak wheat is nearly identical with Kubanka except in being more resistant to stem rust. It was selected from Kubanka (C. I. No. 1440) at the Dickinson (N. Dak.) substation in 1915 and was first distributed to farmers in 1923.

COMMON WHEATS

Kota.—The Kota variety has awned spikes, glabrous white glumes, and hard red kernels. It lodges easily on rich or wet soils. It is very resistant to stem rust, as previously shown, but is susceptible to leaf rust and loose smut. It usually outyields Marquis in North Dakota and adjoining States and has good milling and bread-making qualities. Kota was introduced to this country from Russia in 1903 and in 1918 was discovered to be resistant to black stem rust. It was first distributed to farmers by the North Dakota Agricultural Experiment Station. During the six years it has been commercially grown it has not significantly increased in susceptibility to black stem rust.

Progress.—The Progress variety has awned spikes, glabrous white glumes, and soft to semihard red kernels. The kernels are of softer texture than most other hard red spring wheats. This wheat is rather early and somewhat rust evasive, but also is rather resistant to stem rust.

Progress was selected from the Java variety at the Ashland (Wis.) Branch Experiment Station in 1911. It has been distributed on a limited scale in Wisconsin.

Marquillo (C. I. No. 6887).—This wheat, developed from a Marquis \times Iumillo cross, is a common awnless wheat having glabrous white glumes and hard red kernels. It is a selection from a hybrid between Marquis and Iumillo, the latter a rust-resistant durum wheat made at University Farm, St. Paul, Minn. It has the characters of the Marquis parent except in being more resistant to rust and in producing a leaf more yellow in color.

Marquis × *Kota* (C. I. No. 6898).—This *Marquis* × *Kota* hybrid selection has awned spikes, glabrous white glumes, and hard red kernels. It is not entirely uniform in some characters but apparently is more rust resistant than *Kota*. The wheat is a selection from a hybrid between *Marquis* and *Kota* made at the North Dakota Agricultural Experiment Station.

Reliance (C. I. No. 7370).—This *Kanred* × *Marquis* production has awned spikes, glabrous white glumes, and hard red kernels. It is a true spring wheat. Under the conditions of these experiments it was less susceptible to rust than *Marquis*. This wheat is a selection made at the Chico (Calif.) Field Station from a hybrid between *Kanred* and *Marquis*, the original cross having been made at the Moro (Oreg.) Branch Station in 1917. The rust resistance and spring habit of this strain were determined at University Farm, St. Paul, Minn. Its high yielding ability was determined in experiments at Moccasin, Mont., and Dickinson and Mandan, N. Dak.

SUMMARY

Black stem rust probably causes greater losses to the spring-wheat crop than all other diseases combined. Nearly all of the hard red spring-wheat varieties now grown are very susceptible to rust. Some varieties of durum wheat are much more susceptible than others.

Uniform spring-wheat nurseries were sown at 39 experiment stations in the United States and Canada during one or more of the six years from 1919 to 1924, inclusive. The percentages of infection of stem rust of the 33 varieties of wheat which were grown in all or some of the uniform nurseries are reported in this circular. Percentage estimates of rust infection were recorded in 107 of the 113 station years during which the nurseries were grown. Heavy rust infection occurred at most stations each year.

The durum wheats were much more resistant as a class than the hard red spring wheats. *Pentad*, *Monad*, *Acme*, and *Nodak* are the most resistant.

Kota and a few new hybrid wheats are much more resistant to rust than *Marquis*. *Marquis* escapes rust slightly better than *Power*, *Preston*, and *Haynes Bluestem*. Except for the resistant varieties, the average rust infection on the common wheats increased with the lateness of the average date of maturity of the varieties. Early varieties evade rust better than *Marquis*.

The two varieties of spring emmer were nearly immune to rust.

The reduction of losses from stem rust of wheat by growing resistant varieties is a certain and feasible method. The varieties to grow depend upon local adaptation and market value as well as rust resistance.

**ORGANIZATION OF THE
UNITED STATES DEPARTMENT OF AGRICULTURE**

January 30, 1926

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